APPENDIX IV.

PARENT APPLICATION 09/218,067

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Ellen Peacock
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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

WELLSITE CHEMICAL INJECTION AND MONITORING SYSTEM

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BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to oilfield operations and more particularly to a system for remotely monitoring and controlling apparatus that inject precise amounts of additives or chemicals into a wellbore or into wellbore fluid treatment or processing units at the wellsite.

2. Background of the Art

In production wells, chemicals (also referred to herein as "additives") are often injected from a surface source into the wells to treat the formation fluids flowing through such wells. A developed oil field may contain several oil wells. Frequently between ten to thirty oil wells are drilled from a single offshore location.

Frequently, one or more chemicals are injected into producing wells to, among other things, enhance production through the wellbore, or to control hydrogen sulphide corrosion, scale, paraffin, emulsion and hydrates. Such chemicals are usually injected through a conduit or tubing that is run from the

surface to a known depth. Also, chemicals are introduced in connection with electrical submersible pumps (as shown for example in U.S. Patent No. 4,582,131 (assigned to the assignee hereof and incorporated herein by reference) or through an auxiliary line associated with a cable used with the electrical submersible pump (such as shown in U.S. Patent No. 5,528,824 assigned to the assignee hereof and incorporated herein by reference). Injection of chemicals into fluid treatment apparatus at the surface at the well site is also known.

Typically, a high pressure pump is used to inject a chemical from a source at the wellsite. The pump is usually operated continuously. The pump speed is set to control the amount of the injected fluid. Typically, a separate pump and an injector is used for each type of chemical for each well. Production wells are usually unmanned and many such wells are in very remote areas or on substantially unmanned offshore platforms. A recent survey of certain wellbores revealed that as many as thirty percent (30%) of chemical pumping systems at unmanned locations were either injecting incorrect amounts of the desired chemical or were totally inoperative. Incorrect chemical injection can lead to reduced production of hydrocarbons, clog the perforations or the various flow valves and other downhole equipment or increase the formation of corrosion scale, paraffins, emulsion and hydrates, thereby reducing the

effectiveness of the well and the operating life of the equipment in the wellbore, which can lead to very expensive rework operations, or in extreme situations, generation of dangerous levels of hydrogen sulphide and the abandonment of the wellbore.

Commercially used chemical injection apparatus usually require periodic manual inspection to determine whether the chemicals are correctly being dispensed. It is important for the industry to have chemical injection systems which can inject relatively precise amounts of chemicals, periodically or continuously determine the precise amount of the chemical being dispensed and transmit operational the status of the injection system to a remote location so that appropriate action can be taken. The system should also include self-adjustment within defined parameters. Such a system should also be developed for monitoring and controlling chemical injection into multiple wells at a wellsite, such as an offshore production platform. Manual intervention in the system to address other operational requirements at the wellsite should also be available.

The present invention addresses the above-noted problems associated with wellsite chemical injection systems and provides a system which dispenses relatively precise amounts of chemical, determines the dispensed amount, takes certain corrective actions at the wellsite, communicates with a remote location,

takes

controls corrective actions locally, and/or receives commands from such remote locations and takes corrective actions in response to such commands.

SUMMARY OF THE INVENTION

The present invention provides a system that monitors, at the wellsite, injection of additives into formation fluids recovered through wellbores and controls the supply of such additives, including with input from remote locations as appropriate. The system includes a pump that supplies under pressure a selected additive from a source at the wellsite into the wellbore via a suitable supply line. A flow meter in the supply line measures the flow rate of the additive through the supply line and generates signals representative of the flow rate. A controller at the wellsite controls the pump to control the flow rate of the additive to the well and determines from the signals of the flow meter the chemical flow rate and displays it on a display. The controller interfaces with a suitable two-way communication link and transmits signals and data representative of the flow rate to a second controller at a remote location. The remote controller may be a computer and may be used to transmit command signals to the wellsite controller representative of any change desired for the flow rate. The wellsite controller adjusts the flow rate of the additive to the wellbore to achieve the desired level of chemical additives.

The wellsite controller is microprocessor based and may be programmed to adjust the flow rate automatically when the calculated flow rate is outside predetermined limits. The flow rate is increased when it falls below a lower limit and decreased when it exceeds an upper limit.

The system of the present invention may be configured for multiple wells at a wellsite, such as an offshore platform. Such a system includes a separate pump, a fluid line and wellsite controller for each well. Alternatively, a suitable controller may be provided in communication with and in control of the pump for each well via separate connections or via a bus using addressable signaling. A separate flow meter provides signals representative of flow rate to the controller. The wellsite controller(s) may be programmed to display the flow rates in any order. The wellsite controller(s) transmit flow rate signals to the remote controller and adjust the flow rate to each well in response to the command signals received from the remote controller. The wellsite controller preferably periodically polls each flow meter and performs the above described functions. If a common additive is used for a number of wells, a common additive source may be used. A common pump may also be used with a separate control valve in each supply line that is controlled by the controller to adjust respective the flow rate.

A suitable precision low flow, flow meter such as, for example, a nutating flow meter is used to make relatively precise measurements of the flow rate of the injected chemical. Any positive displacement type flow meter could also be used. The controller is environmentally sealed and can operate over a wide temperature range of temperatures. The present system is adapted to port to a variety of software and communications protocols and may be retrofitted on the commonly used manual systems.

The above described systems can also be used monitor the chemical injection into surface treatment units at the wellsite and to control the injection amounts from any remote location.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiments, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

Figure 1 is a schematic illustration of a chemical injection and monitoring system according to one embodiment of the present invention.

Figure 1A shows an alternative manner for controlling the operation of the high pressure pump.

Figure 1B shows a circuit for providing some measure of manual control of the controller for high pressure pump **22**.

Figure 2 shows a functional diagram depicting one embodiment of the system for controlling and monitoring the injection of additives into multiple wellbores, utilizing a central controller on an addressable control bus.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 is a schematic diagram of a chemical injection system **10** according to one embodiment of the present invention. The system **10**, in one aspect is shown, as injecting and monitoring the chemicals into a wellbore **50** and in another aspect injecting and monitoring chemicals into a surface treatment or processing unit **80**. The wellbore **50** is shown to be a production well using typical completion equipment downhole. The wellbore **50** has a production zone **52** which has multiple perforations **54** through the formation **55**. Formation fluid **56** enters a production pipe **60** in the well **50** via perforations **54** and passages **62**. A screen **58** in the annulus **51** between the

production pipe **60** and the formation **55** prevents the flow of solids into the pipe **60** and also reduces the fluid velocity into the production pipe **60** to acceptable levels. An upper packer **64a** above the perforations **54** and a lower packer **64b**, in the annulus **51** respectively, isolate the production zone **52** from the annulus **51a** above and annulus **51b** below the production zone **52** A flow control valve **66** in the production pipe **60** can be used to control the fluid flow to the surface **12**. A flow control valve **67** may be placed in the pipe **62** below the perforations to control fluid flow from any production zone below the production zone **52**.

A smaller diameter tubing, such as tubing **68**, may be used to carry the fluid from the production zones to the surface. A production well usually includes a casing **40** near the surface and a wellhead equipment **42**. The wellhead equipment generally includes a blow-out prevention stack **44** and passages for supplying fluids into the wellbore. Valves (not shown) are provided to control fluid flow to the surface. Wellhead equipment and production well equipment, such as shown in the production well **60**, are well known and thus are not described in greater detail.

As noted above, chemicals or additives are commonly injected in wellbores to control corrosion, scale, paraffins, emulsion and hydrates. A

variety of chemical injection systems are commercially available. The desired chemical is injected into the well via an injection tubing that runs from the surface to the desired wellbore depth. A pump supplies the chemical under pressure. A wellhead manifold is installed in the injection tubing at the surface to control pressure. One such system is commercially available from Baker Hughes Incorporated, the assignee of this application.

Referring back to **Figure 1**, in the present invention, the desired chemical **13** is injected into the wellbore **50** via an injection line **14** from a source **16** by a suitable high pressure pump such as a positive displacement pump **18**. The chemical **13** flows through the line **14** and discharges into the production tubing **60** near the production zone **52** via inlets or passages 15 ~~**18**~~. The same or different injection lines may be used to supply chemicals to different production zones. In **Figure 1**, the line **14** is shown extending to the production zone below the zone **52**. //

Separate injection lines allow injection of different additives at different well depths. A suitable high-precision, low-flow, flow meter such as, for example, nutating flow meter **20**, measures the flow rate through line **14** and provides signals representative of the fluid flow rate. The pump **18** is operated by a suitable device **22** such as a motor or other device. The stroke of the

The pump stroke

pump **18** defining fluid volume output per stroke and/or the pump speed are controlled, e.g., by a 4 - 20 mA control signal, to control the output of the pump **18**.

In the present invention, a controller **80** controls the operation of the pump **18**, either utilizing programs stored in a memory **91** associated with the controller **80** or instructions provided to the controller **80** from a remote controller or processor **82**. The controller **80** includes a microprocessor, resident memory both for storing the programs, such as read only memories (ROM) and for storing data, such as in random access memories (RAM). The microprocessor, utilizing signals from the flow meter **20** and programs stored in the controller **80** determines the flow rate of the additive and displays such flow rate on the display **81**. The controlled can be programmed to alter the pump speed (or rpm) and/or pump stroke to deliver the desired amount of the chemical **13**. The pump speed is increased if the measured amount of the chemical injected is less than the desired amount and decreased if the injected amount is greater than the desired amount. The controller **80** also includes circuits and programs, generally designated by numeral **91**, to provide interface with the onsite display **81**, interface with converter **83** and to perform other desired functions.

The controller **80** polls the flow meters provides chemical injection flow rate measurement signals to a suitable interface **83**, such as RS-485, which transmits the data to the remote controller **82**. The data may be transmitted via any suitable two-way data link. Such data links may include, among other things, telephone modems, radio frequency transmission, microwave transmission and satellites. The remote controller **82** is preferably a computer-based system and can transmit command signals to the controller **80** via the link **85**. The remote controller is provided with models/programs and can be operated manually and/or automatically to determine the desired amount of the additive to be injected. If the desired amount differs from the measured amount, it sends corresponding command signals to the wellsite controller **80**. The controller **80** receives the command signals and controls the flow rate of the chemical injection of the chemical **13** into the well **50** accordingly.

The controller **80** preferably includes protocols so that the flow meter **20**, pump control device **22**, and communication modules or links **83** made by a different manufacturers can be utilized in the system of this invention. In the oil industry, the analog output for pump control is typically configured for 0-5 VDC or 4-20 milliamps (mA) signal.

In one mode of the present invention, the controller **80** can be

programmed to provide such control. This allows for the system **10** to be used with existing pump controllers. A suitable source of electrical power, e.g., a solar-powered unit **89** or DC power, AC power, or on site generators (not shown) provides power to the controller **80**, converter **83** and other circuit elements. The wellsite controller **80** is also provided with a display that displays the flow rates corresponding to the individual flow meters. This display may be scrolled by an operator so that any of the flow meters may be viewed. This display is controllable either by a signal from the remote controller or by a suitable interrogation device at the well site, such as an infrared device (not shown). This makes it possible for an operator at the wellsite to view the displayed data in the controller non-intrusively without taking apart the protective casing of the controller.

Still referring to **Figure 1**, the produced fluid **69** received at the surface is processed by a treatment unit or processing unit **75**. The surface processing unit **75** may be of the type that processes the fluid **69** to remove solids and certain other materials such as hydrogen sulphide or that processes the fluid **69** to produce semi-refined to refined products. In such systems, it is desired to periodically or continuously inject certain chemicals. A system, such as system **10** shown in Figure 1 can be used for injecting and monitoring chemicals into the treatment unit **75**.

In addition to the flow rate signals **21** from the flow meter **20**, the controller **80** may be configured to receive signals representative of other parameters, such as the rpm of the pump **18**, or the motor **22** or the modulating frequency of a solenoid valve. In one mode of operation, the controller **80** periodically polls the meter **20** and automatically adjusts the pump controller **22** via an analog input **22a** or alternatively via a digital signal of a solenoid controlled system. The controller **80** also can be programmed to determine whether the pump output, as measured by the meter **20**, corresponds to the level of signal **22a**. This information can be used to determine the pump efficiency. It can also be an indication of a leak or another abnormality. Other sensors **94**, such as vibration sensors, temperature sensors may be used to determine the physical condition of the pump **18**. Sensors which determine the properties of the wellbore fluid can provide information of the treatment effectiveness of the chemical being injected , which information can then also be used to adjust the chemical flow rate.

Figure 1A shows an alternative manner for controlling the high pressure pump. This configuration includes a control valve, such as a solenoid valve **102**, in the supply line **106** from a source of fluid under pressure (not shown) for the pump controller **22**. The controller **80** controls the operation of the valve via suitable control signals, such as digital signals, provided to the valve

102 via line **104**. The control of the valve **22** controls the speed or stroke of the pump **22** and thus the amount of the additive supplied to the wellbore **50**. The valve **102** may be modulated to control the pump **18**.

The automated modes of operation (both local and/or from remote location) of the injection system **10** are described above. In many cases, it is desirable to operate the control system **10** in a manual mode, such as by an operator at the wellsite. Manual control may be required to override the system because of malfunction of the system or to repair parts of the system **10**. **Figure 1B** shows a circuit for manual control of the high pressure pump **22**. The circuit includes a switch **120** in the controller (see **Figure 1**), which in first or normal position allows the analog signal **22a** from the controller to control the pump **22** and in the second position allows the manual circuit **124** to control the pump **22**. The circuit in one embodiment may include a current control circuit, such as a rheostat **126** that enables the operator to set the current at the desired value. In the preferred embodiment, the current range is set to between 4 and 20 ma, which is compatible with the current industry protocol. The remaining functions of the controller **80**, such as the flow rate display, etc. continues to operate. Additionally, the controller is designed to interface with manually remote devices, such as infrared devices. This allows the operator to communicate with and control the operation of the controller **80** while at the

well site, e.g., to calibrate the system, without disassembling the controller **80**. This operator control includes resetting the allowable ranges for the flow rate and/or setting a value for the flow rate.

As noted above, it is common to drill several wellbores from the same location. For example, it is common to drill 10-20 wellbores from a single offshore location. After the wells are completed and producing, a separate pump and meter is installed to inject additives into each such wellbore. **Figure 2** shows a functional diagram depicting one system **200** for controlling and monitoring the injection of additives into multiple wellbores **202a-202m**. In the configuration of **Figure 2**, a separate pump supplies an additive from a separate source to each of the wellbores **202a-202m**. Pump **204a** supplies an additive from the source **206a**. Meter **208a** measures the flow rate of the additive into the wellbore **202a** and provides corresponding signals to a central controller **240**. The controller in response to the flow meter signals and the programmed instructions or instructions from a remote controller **242** controls the operation of pump control device **210a** via a bus using addressable signaling for each pump controller. Alternatively, the controller **80** may be connected to the pump controllers via a separate connection to each controller. Furthermore, a plurality of wellsite controllers, one for each pump may be provided, with this plurality of controllers communicating with the remote controller via a bus or other

suitable connection. The controller also receives signal from sensors S1a associated with pump **204a** via line **212a** and from sensors S2a associated with pump controller **210a** via line **212a**. Such sensors may include rpm sensor, vibration sensor or any other sensor that provides information about a parameter of interest of such devices. Additives to the wells **202b-202m** are respectively supplied by pumps **204b-204m** from sources **206b-206m**. Pump controller **210b-210m** respectively control pumps **204b-204m** while flow meters **208b-208m** respectively measure flow rates to the wells **202b-202m**. Lines **212b-212m** and lines **214b-214m** respectively communicate signal from S1b-S1m and S2b-S2m to the central controller **240**. The controller **240** utilizes memory **246** for storing data and programs stored in memory **244** in the manner described above in reference to system **10** for controlling the pumps and for displaying information on the display **250**. A suitable two-way link allows data and signals communication between the central controller **240** at the well site and the remote controller **242**. The individual controllers would communicate with the sensors, pump controllers and remote controller via suitable corresponding connections.

The central controller **240** controls each pump independently. The controller can be programmed to compute the condition of each pump and the controller from the sensor signals. For example the controller can be

WHAT IS CLAIMED IS:

1. A system for monitoring at a wellsite supply of additives to formation fluid recovered through a wellbore and controlling said supply from a remote location, said system comprising:

(a) a flow control device controlling the flow rate of the supply of a selected additive from a source thereof at the wellsite into said formation fluid via a supply line;

(b) a flow measuring device measuring the flow rate of the additive supplied to said formation fluid and generating signals indicative of said flow rate;

(c) a first controller at the wellsite determining the flow rate of the additive from the signals of the flow measuring device and transmitting signals representative of the flow rate to the remote location; and

(d) a second controller at said remote location receiving signals transmitted by said first controller and in response thereto transmitting command signals to said first controller representative of a desired change in the flow rate of additive supplied;

wherein the first controller causes the flow control device to control the flow rate of the supply of said additive in response to the command

signals.

2. The system of claim 1 wherein said first controller includes a display that displays at least the flow rate of the additive supplied to the formation fluid.

3. The system of claim 1 wherein the additive is supplied to one of (a) a location in the wellbore and (b) a hydrocarbon processing unit processing said formation fluid at the wellsite.

4. The system of claim 1 wherein the flow measuring device is a positive displacement flow meter.

5. The system of claim 1 wherein the flow measuring device is a nutating flow meter.

6. The system of claim 1 wherein the first controller includes a manual override circuit that enables an operator to manually control the operation of the flow control device and thus the flow rate of the additive.

7. The system of claim 1 wherein the first controller includes a microprocessor and programmed instructions for use by the

microprocessor to compute the flow rate.

8. The system of claim 1 wherein the flow control device includes a high pressure pump.

9. The system of claim 8 further including a solenoid valve that controls the operation of said high pressure pump.

10. The system of claim 9 wherein said first controller controls the solenoid pump.

11. The system of claim 1 wherein the second controller is a computer.

12. A system for monitoring at a wellsite supply of additives to a plurality of wells at a common wellsite and controlling said supply from a remote location, said system comprising:

(a) a flow control device controlling the flow rate of supply of a selected additive from a source thereof at the wellsite into each of said plurality of wells via a separate supply line;

(b) a flow measuring device in each said supply line measuring the flow rate of the additive supplied to a corresponding well, each

said flow measuring device generating signals indicative of a flow rate of the additive to its corresponding well;

(c) a first controller at the wellsite determining the flow rate of the additive to each well from the signals of the flow measuring device associated with such well and transmitting signals representative of the flow rate for each well to a remote location; and

(d) a second remote controller at said remote location receiving signals transmitted by said first controller and in response thereto transmitting to said first controller command signals representative of a desired change in the flow rate of additive supplied each said well;

wherein the first controller causes the flow control device to control the supply of additives to each well in response to the district command signals corresponding to said well.

13. The system of claim 12 wherein the additive is supplied to one of (a) a location in one or more e of the plurality of wellbore and (b) a hydrocarbon processing unit processing said formation fluid at the wellsite.

14. The system of claim 12 wherein the flow measuring device in at least

one of supply lines is a positive displacement flow meter.

15. The system of claim 12 wherein the flow measuring device in at least one of supply lines is a nutating flow meter.

16. The system of claim 12 wherein the first controller includes a manual override circuit that enables an operator to manually control the flow rate of the additive.

17. The system of claim 12 wherein the flow control device includes a high pressure pump.

18. The system of claim 17 further including a solenoid valve that controls the operation of said high pressure pump.

19. A method of monitoring at a wellsite supply of additives to formation fluid recovered through a wellbore and controlling said supply from a remote location, said system comprising:

(a) controlling the flow rate of the supply of a selected additive from a source thereof at the wellsite into said formation fluid via a supply line;

(b) measuring with a flow measuring device measuring the flow rate of the additive supplied to said formation fluid and generating a signal indicative of said flow rate;

(c) determining at the wellsite the flow rate of the additive from the signal of the flow measuring device and transmitting a signal representative of the flow rate to the remote location; and

(d) receiving at said remote location signals transmitted from the wellsite and in response thereto transmitting command signals to the wellsite representative of a desired change in the flow rate of additive supplied; and

(e) controlling the flow rate of the supply of said additive in response to the command signals

20. The method of claim 19 further comprising displaying at the well site the flow rate of the additive supplied to the formation fluid.

21. The method of claim 19 further comprising providing a manual override to override the remote control of the flow rate of the additive.

22. The method of claim 19 wherein providing a manual override further comprises an operation selected from (i) setting a flow rate of the

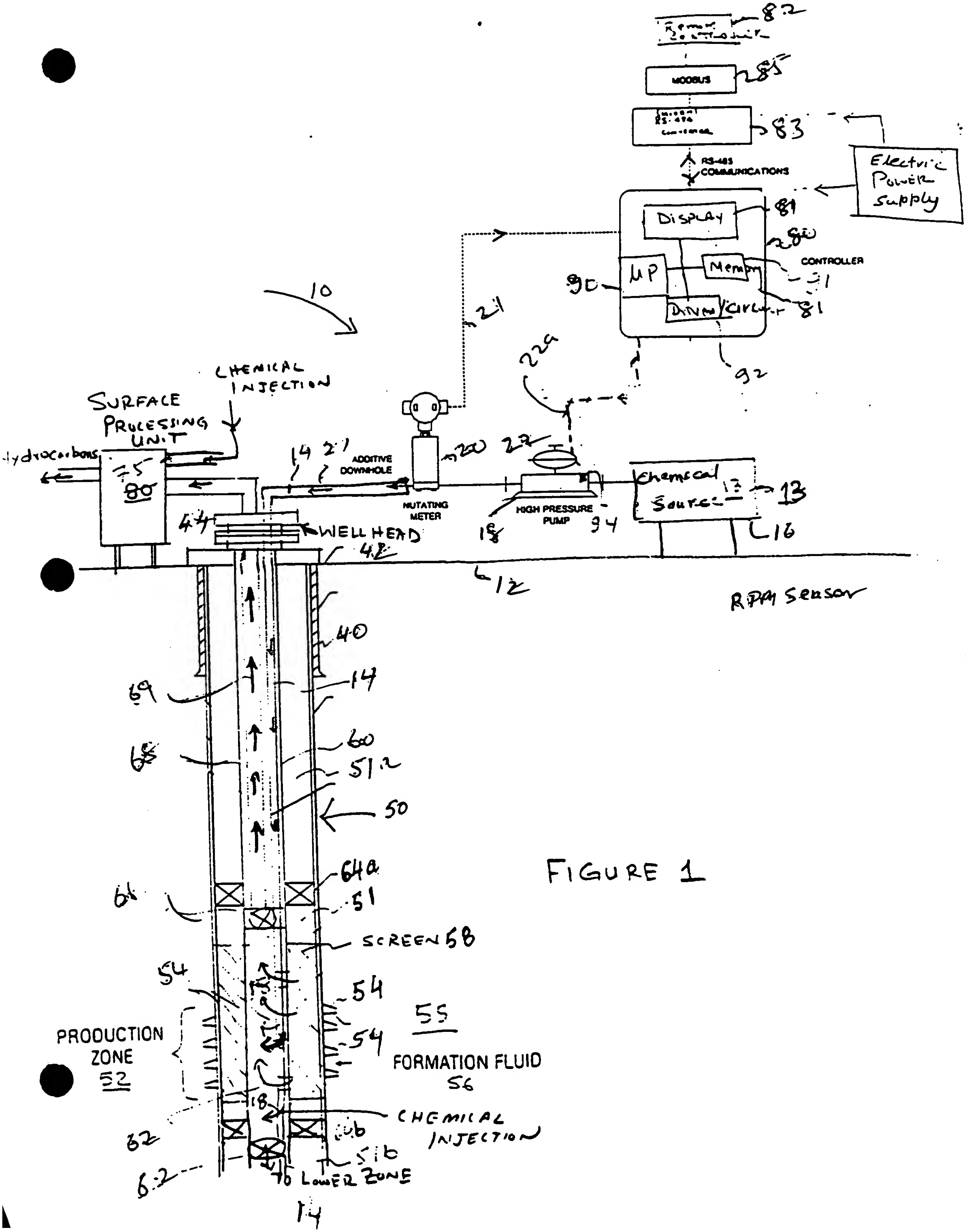
additive, and (ii) setting a range of allowable values for the flow rate of the additive.

ABSTRACT

A system that monitors at the wellsite injection of additives into formation fluids recovered through wellbores controls the supply of such additives from remote locations. A pump supplies under pressure a selected additive from a source at the wellsite into the wellbore via a suitable supply line. A flow meter in the supply line measures the flow rate of the additive through the supply line and generates signals representative of the flow rate. A controller at the wellsite controls the pump to control the flow rate of the additive to the well and determines from the flow meter signals the flow rate. The controller interfaces with a suitable two-way communication link and transmits signals and data representative of the flow rate to a second controller at a remote location. The remote controller transmits command signals to the wellsite controller representative of any change desired for the flow rate. The wellsite controller adjusts the pump speed to alter the flow rate of the additive to the wellbore. The wellsite controller is microprocessor based and may be programmed to adjust the flow rate automatically when the calculated flow rate is outside predetermined limits. The flow rate is increased when it falls below a lower limit and decreased when it exceeds and upper limit. The system of the present invention may be configured for multiple wells at a wellsite, such as an offshore platform.

programmed to determine the vibration and rpm of each such device. This can provide information about the effectiveness of each such pump and the controller. The controller can be programmed to poll the flow rate and the parameters of interest of each pump and the pump controller periodically and the perform the desired computations at the well site and then transmit the results to the remote controller **242** via the telemetry interface **248**. The remote controller **242** may be programmed to determine any course of action from the received information and any other information available to it and transmit corresponding command signals to the wellsite central controller **240**. Again, communication with a plurality of individual controllers would be done in a suitable corresponding manner.

While foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.



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MODBUS
85
83
RS-485 COMMUNICATIONS
Electric Power supply
DISPLAY
81
80
CONTROLLER
UP
Memory
90
Driver
Circuit
81
10
21
22a
92
CHEMICAL INJECTION
SURFACE PROCESSING UNIT
hydrocarbons
75
80
14
21
ADDITIVE DOWNHOLE
20
22
NUTATING METER
HIGH PRESSURE PUMP
Chemical Source
13
18
94
16
44
WELL HEAD
42
12
RPM Sensor
40
69
14
68
60
51a
50
64a
64
51
SCREEN 58
54
54
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To LOWER ZONE
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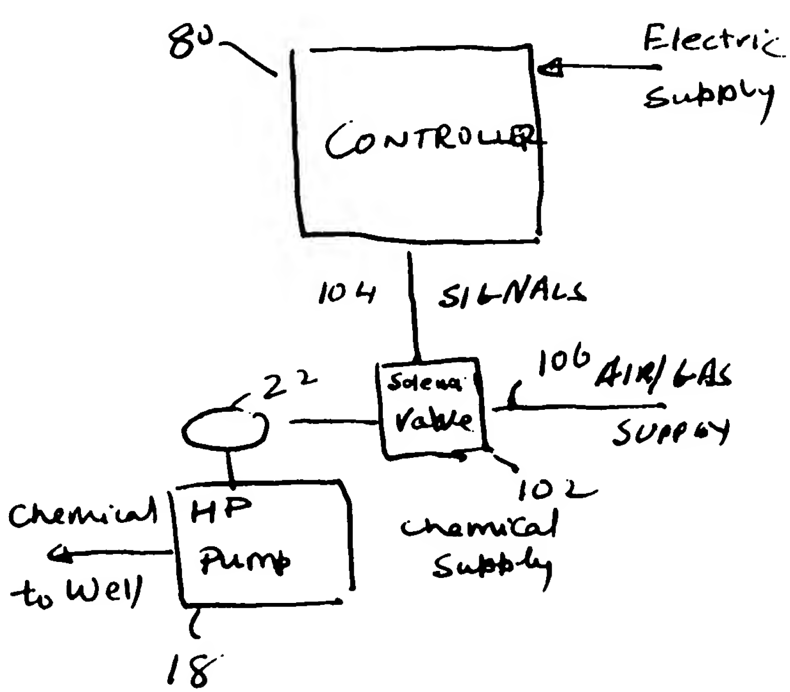
FIGURE 1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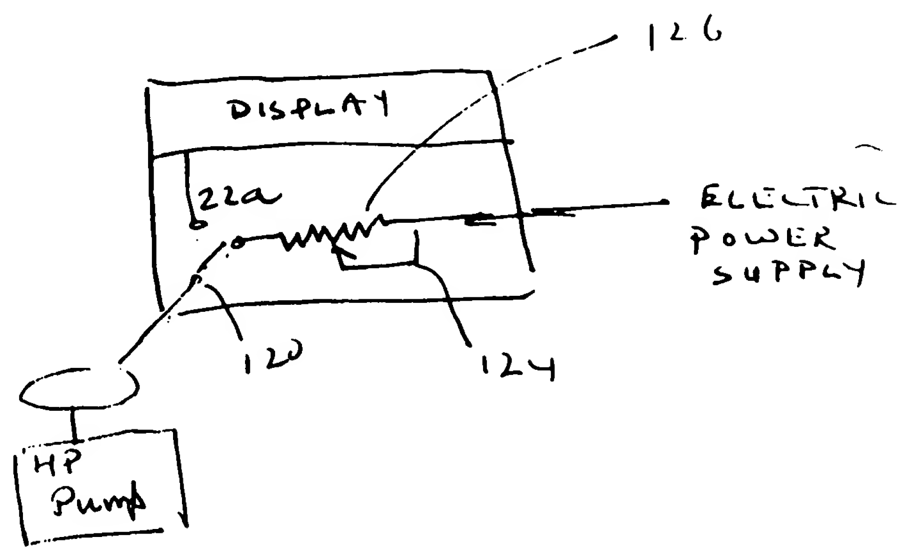
Supply
104
SIGNALS
Solenoid
Valve
106
AIR/GAS
SUPPLY
102
chemical
Supply
22
HP
Pump
Chemical
to Well
18

FIG. 1A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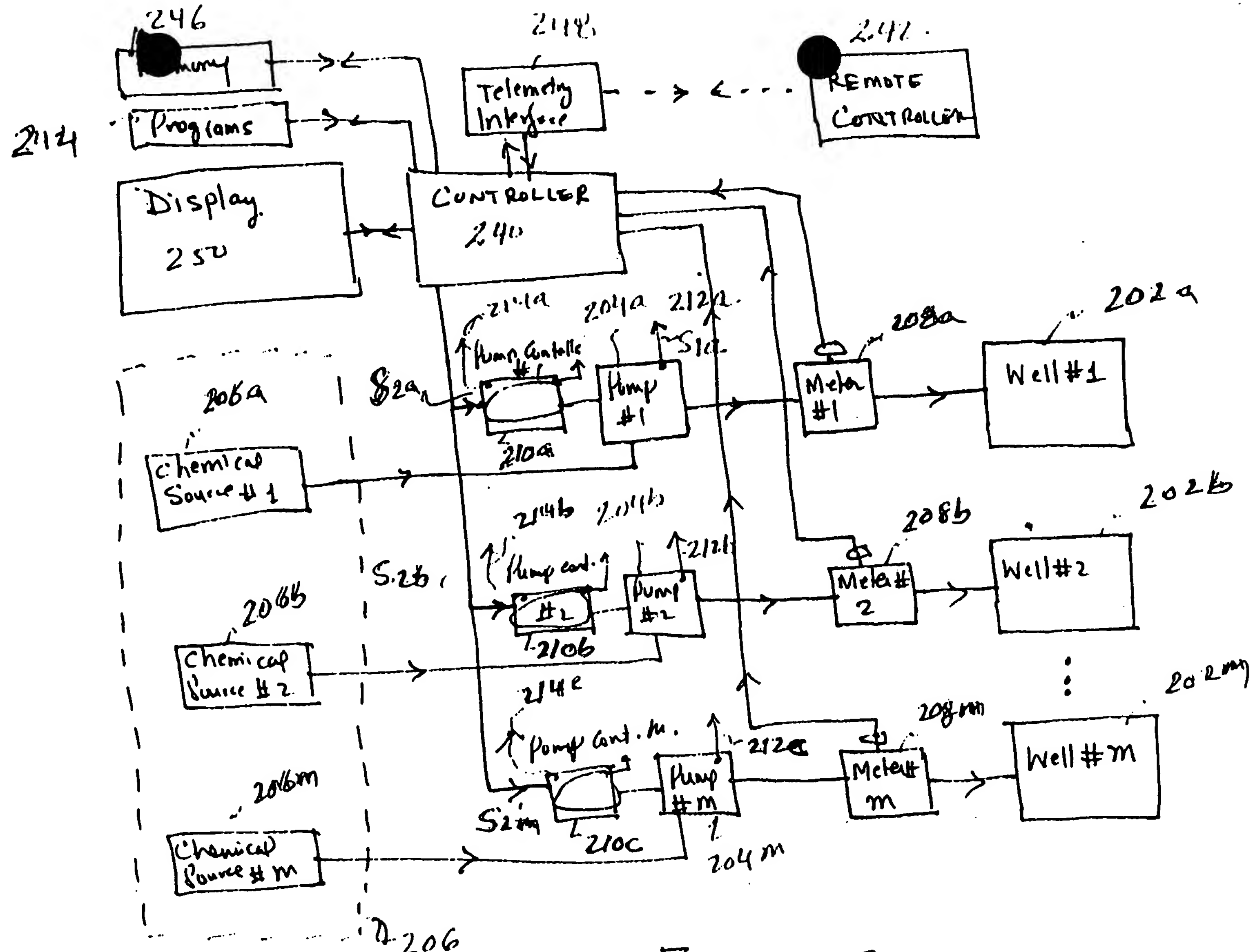
22a
ELECTRIC
POWER
SUPPLY
120
124
HP
Pump

FIG. 1B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Memory
Programs
214
Display
250
Telemetry Interface
248
Remote Controller
242
Controller
240
214a
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S1a
Pump #1
S2a
210a
Meter #1
208a
Well #1
202a
206a
Chemical Source #1
214b
204b
Pump cont.
212b
S2b
#2
Pump #2
210b
Meter #2
208b
Well #2
202b
206b
Chemical Source #2
214c
Pump Cont. M
212c
S2m
Pump #M
210c
204m
Meter M
208m
Well #M
202m
206m
Chemical Source #M
206
FIGURE 2.